Study of Isospin Fluctuations at RHIC-PHENIX

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Contents

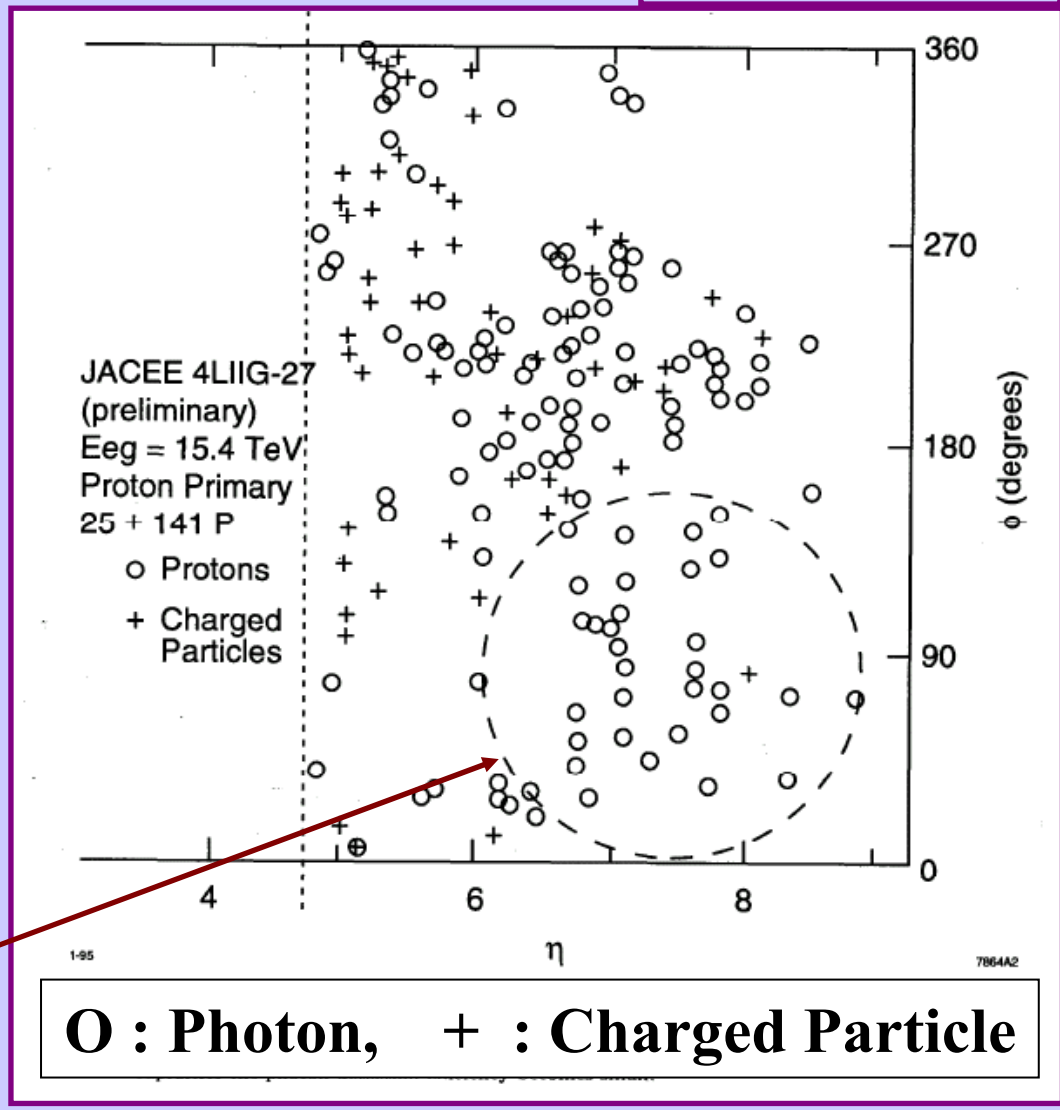
Centauro /Anti Centauro Event

(Cosmic ray experiment)

- **(Brazil-Japan collaboration in Bolivia) Y.Fujimoto and S.Hasegawa, Phys. Rep. 65, 151 (1980)**
- **(JACEE) J.J.Lord and Iwai, Paper No. 515, International Conference on High Energy Physics, Dallas (1992)**

This is anomalous region assuming isospin symmetry.

Anti Centauro



O : Photon, + : Charged Particle

List of Centauro Searches

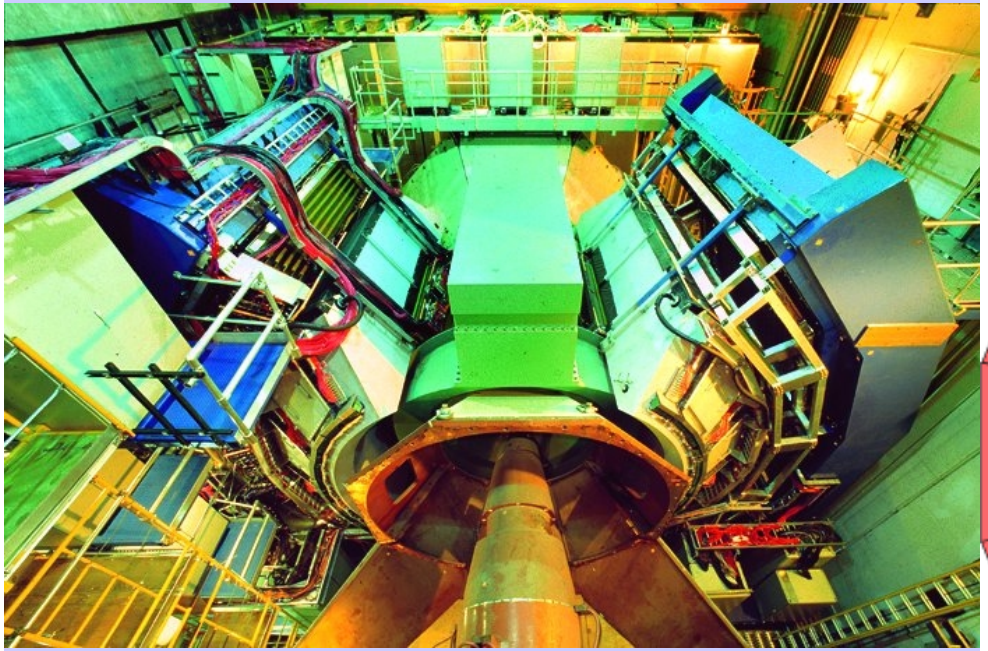
	Experiment	Collaboration	CM Energy	Search Region (η , ϕ)
1980	Mt. Chacaltaya	Brazil-Japan	$\sqrt{s} \geqq 1.7$ TeV	----------
1992	Balloon	JACEE	----------	$5.0 < \eta < 9.0$ $\Delta\phi < 2\pi$
1982	$SP\bar{P}S$	UA5	$\sqrt{s} = 540$ GeV	$\lvert\eta\rvert < 5.0$
1983	$SP\bar{P}S$	UA1	$\sqrt{s} = 540$ GeV	$\lvert\eta\rvert < 3.1$
1986	$SP\bar{P}S$	UA5	$\sqrt{s} = 900$ GeV	$\lvert\eta\rvert < 5.0$
1996	TEVATRON	CDF	$\sqrt{s} = 1.8$ TeV	$\lvert\eta\rvert < 4.2$, , $\Delta\phi < 2\pi$
1997	TEVATRON	MINIMAX	$\sqrt{s} = 1.8$ TeV	$3.4 < \eta < 4.2$
2000	SPS	WA98	$\sqrt{s} = 3.5$ TeV (Pb+Pb)	$2.80 < \eta < 3.75$ $\Delta\phi < \pi$
2001	RHIC	PHENIX	$\sqrt{s} = 39.4$ TeV (Run2 Au+Au)	$\lvert\eta\rvert < 0.35$ $\Delta\phi < 1/2\pi$ ($\times 2$ arm)

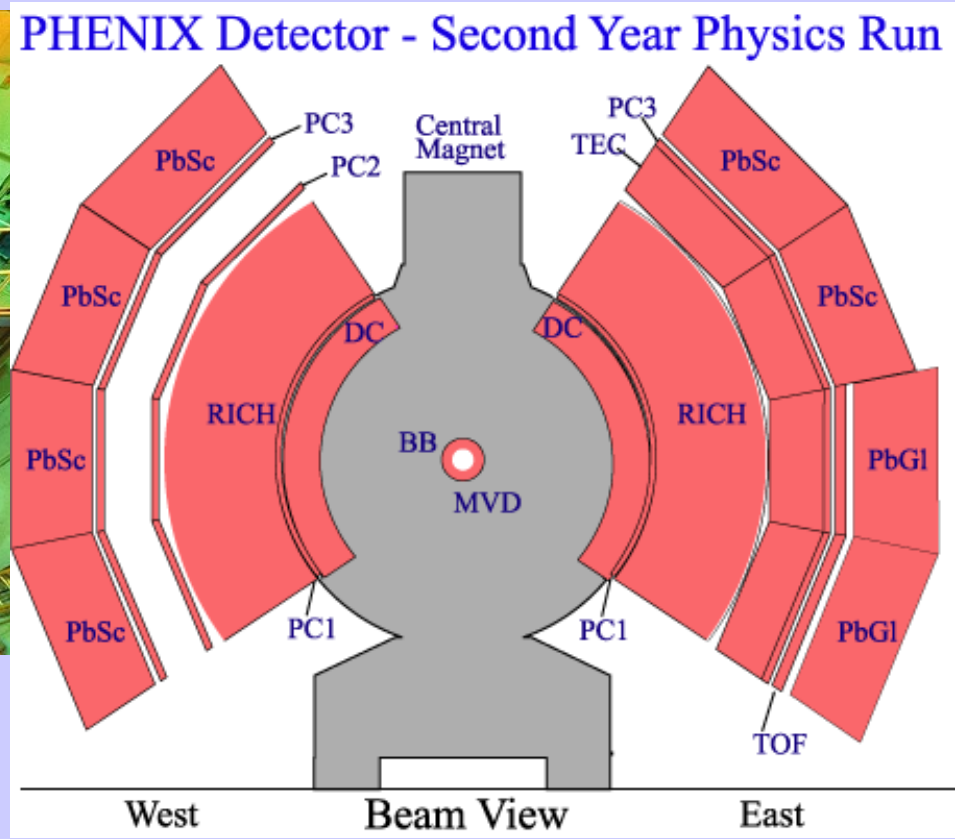
PHENIX Experiment at Run2

Using Magnetic Field-off data

Gamma-like Cluster (Electro-Magnetic Calorimeter)

Charged Track (Drift Chamber and Pad Chamber1)

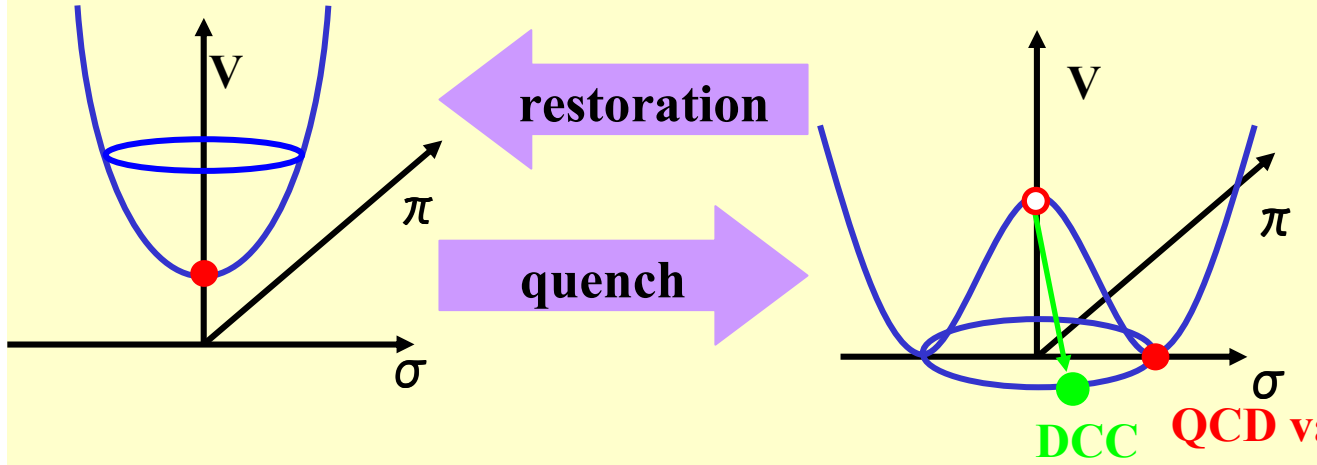




$-\ 0.35\ <\ \eta\ <\ 0.35$

$\Delta\ \phi\ <\ 1\ /\ 2\ \pi$ in each arm

Disoriented Chiral Condensate



(Quench Mechanism)
K.Rajagopal and
F.Wilczek : Nucl. Phys.
B379, 395 (1993)

Chiral transformation

$$\begin{pmatrix} u \\ d \end{pmatrix} \rightarrow e^{i\gamma^5 \tau\cdot\theta} \begin{pmatrix} u \\ d \end{pmatrix}$$

Linear sigma model

$$\vec{\phi}_i = (\sigma, \pi)$$

$$L = \frac{1}{2}\partial_\mu \phi_i \partial^\mu \phi_i - \frac{1}{4}\left(\phi^2 - v^2\right)^2 + H\sigma$$

Chiral symmetry breaking term due to finite masses

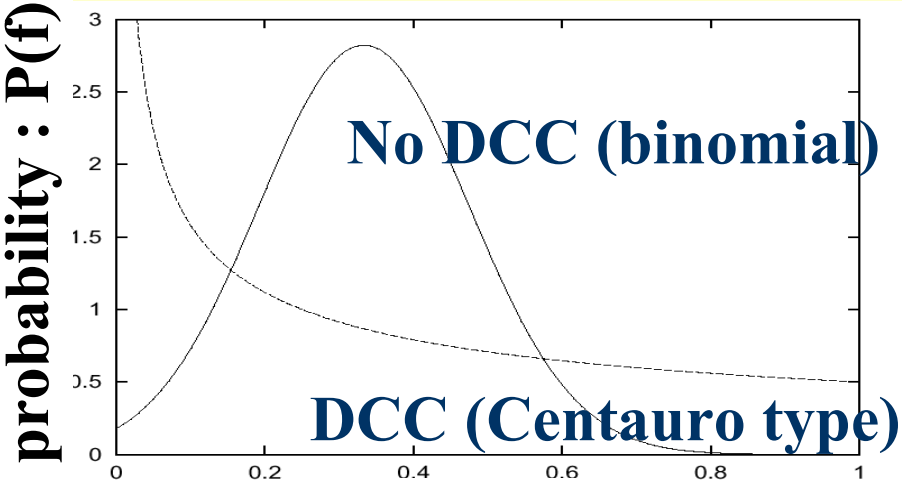
Search Strategy

If every event could contain largely deviated domains on isospin symmetry and most of domains per event could be detected within a limited detector acceptance, we would be able to discuss anomaly based on the probability distribution by the statistical treatment like:

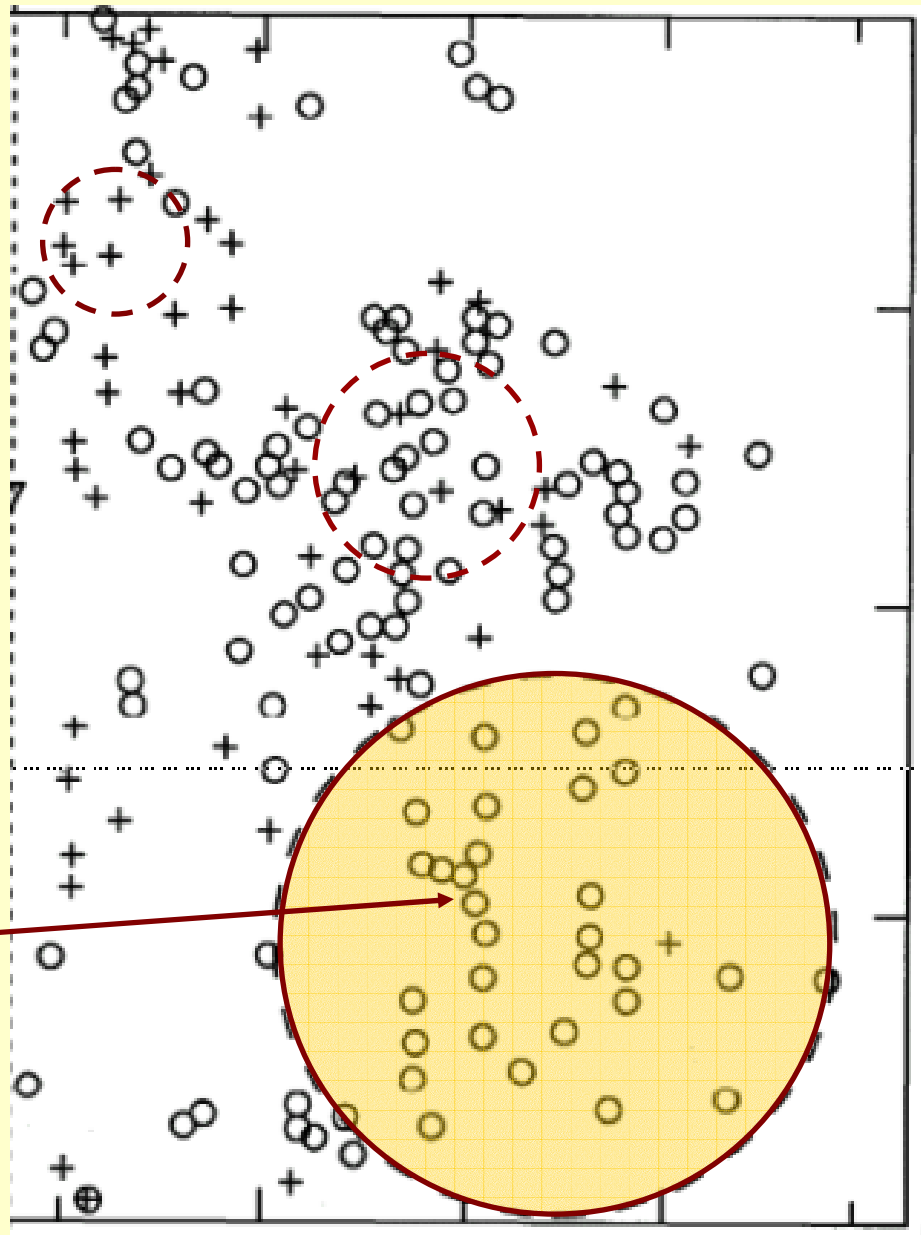
$$fraction\ :\ f = \frac{n_{\pi^0}}{n_{\pi^0} + n_{\pi^+} + n_{\pi^-}}$$

$$probabilit\ y : P(f)df = \frac{1}{2\sqrt{f}}df$$

However, we do not know domain information on the numbers and sizes a priory, and our detector acceptance is very limited. Therefore we need to search for rare events containing anomalous domain like cosmic ray experiments rather than statistical treatment above.



We search for a most largely deviated domain per event by looking at differences between number of charged and gamma-like clusters by changing regions of interest as we do by eyes, because we don't know what the size is and where the position is.



We want to extract this region. We must do this search in several million events.

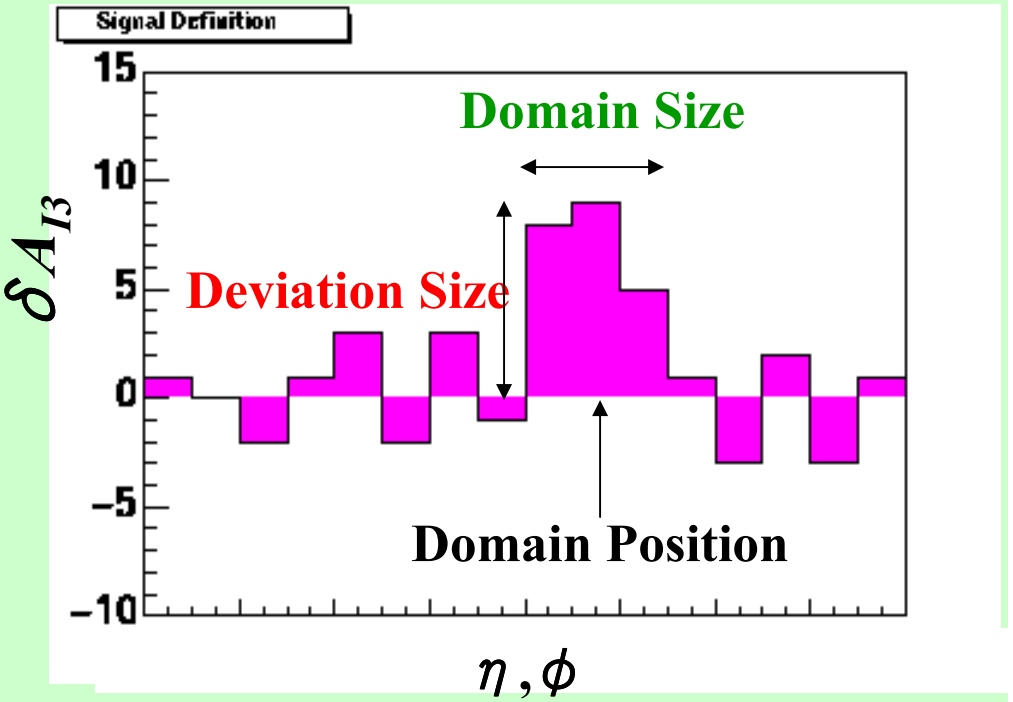
Observables

Definition of asymmetry between number of charged tracks and neutral clusters event-by-event base as a function of subdivided eta-phi phase spaces normalized by 1 sigma of standard deviation for given multiplicity.

$$\delta A_{I_3}(\Delta\eta\Delta\phi) \equiv \frac{N_{\pi^\pm}(\Delta\eta\Delta\phi) - N_\gamma(\Delta\eta\Delta\phi)}{\sqrt{N_{\pi^\pm} + N_\gamma}}$$

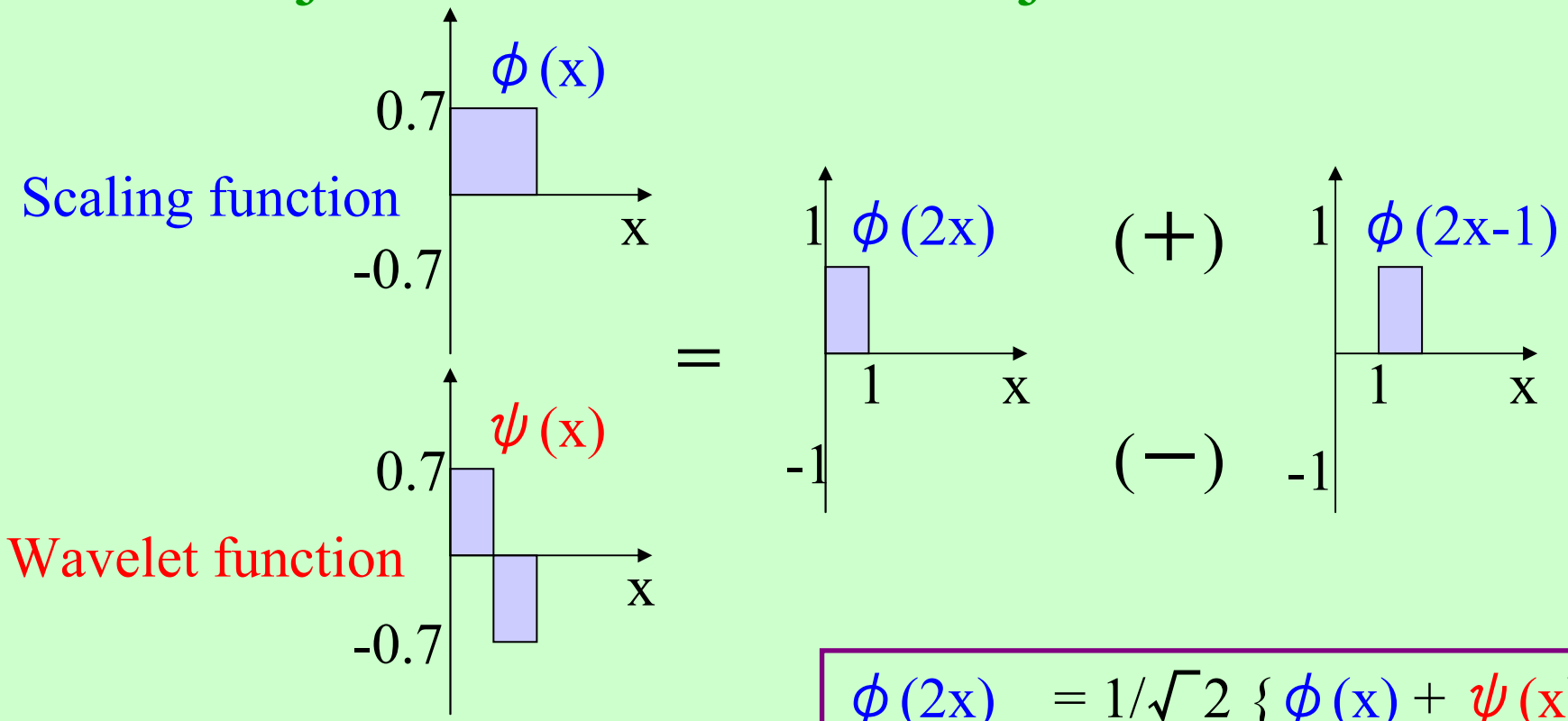
$$\approx \frac{N_{ch}(\Delta\eta\Delta\phi) - N_\gamma(\Delta\eta\Delta\phi)}{\sqrt{N_{ch} + N_\gamma}}$$

Domain Size and Domain Position of large deviated region can be obtained at the same time by using Multi Resolution Analysis (MRA) technique.



Multi Resolution Analysis (MRA)

Level j-1 : 2^{j-1} bins Level j : 2^{j} bins



$$\phi(2x) = 1/\sqrt{2}\,\{\phi(x) + \psi(x)\}$$
$$\phi(2x-1) = 1/\sqrt{2}\,\{\phi(x) - \psi(x)\}$$

Total number of bins is 2^{j}

Level j correspond to resolution level

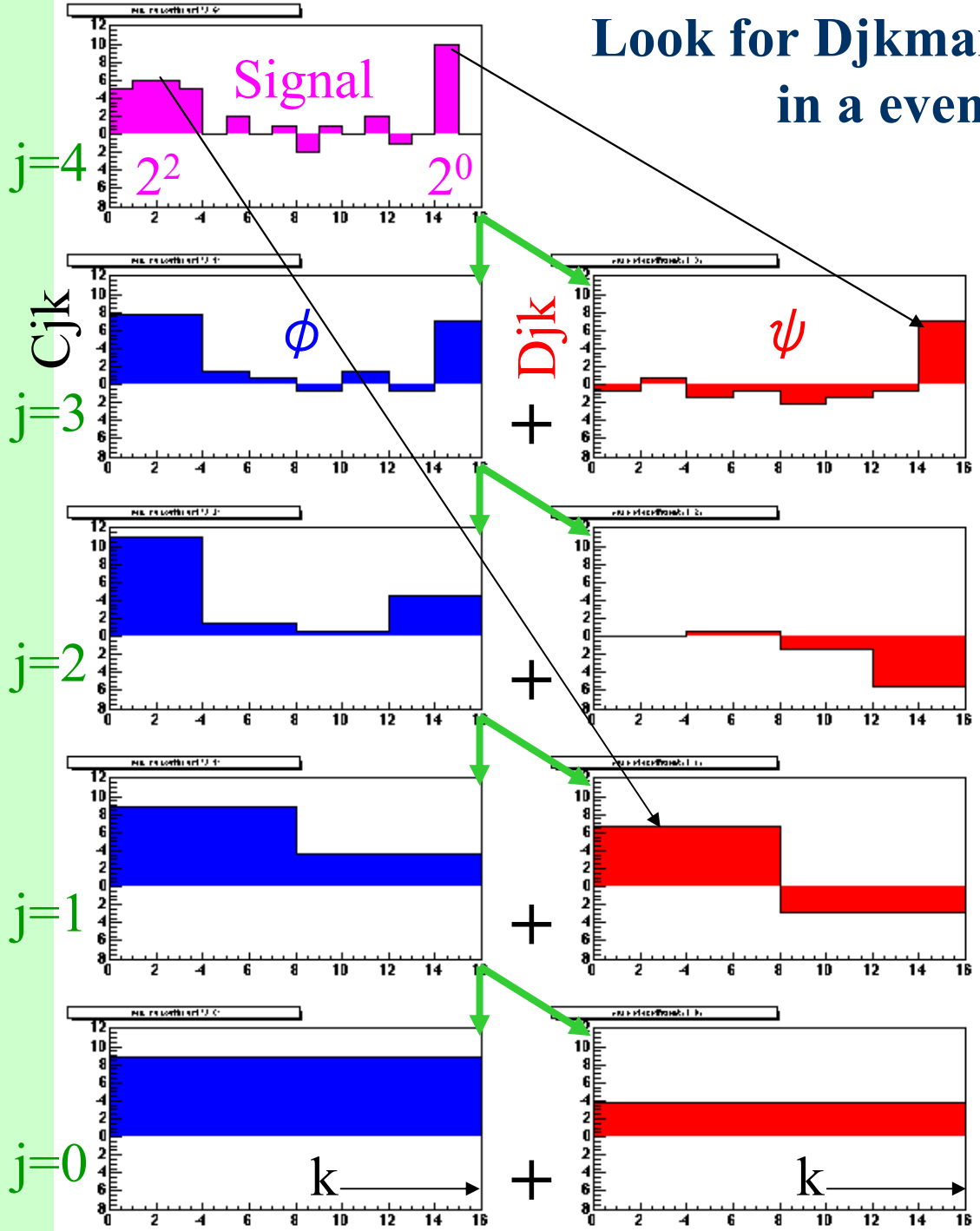
Signal Decomposition

j : resolution level
k : k-th bin in pseudo rapidity
Cjk : coefficients of ϕ
Djk : coefficients of ψ

$1/2^j$ → Domain Size

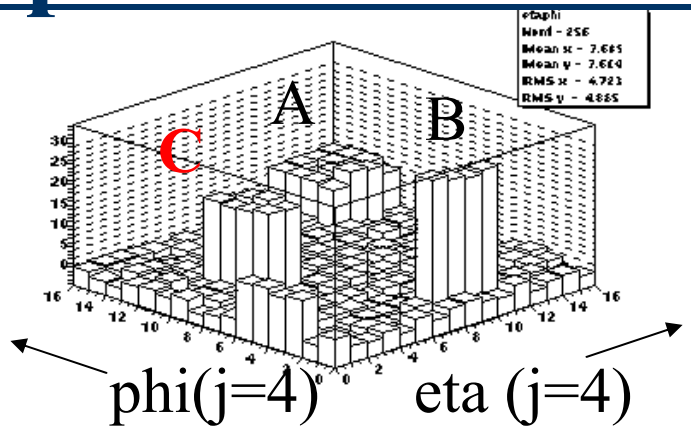
k → Phase Space Position

Djk → Deviation Size



Look for Djkmax in a event

Example of 2D MRA



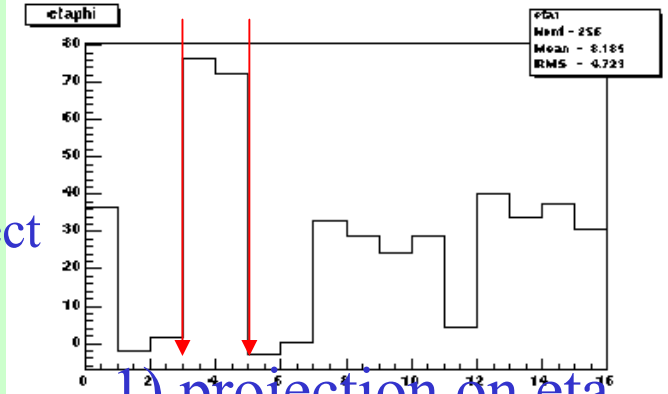
Domain C:
A_{I3}= ~20 x 8bins
$(\eta, \phi)=(3, 7)$
$(j_\eta , j_\phi)=(3, 2)$

Result:Correct

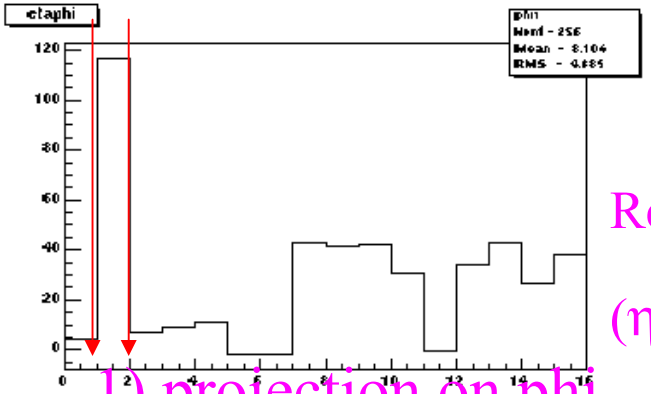
$(\eta,\phi)=(3,7)$

$(j_\eta,j_\phi)=(3,2)$

$Djkmax^2$ =4392.42



1) projection on eta



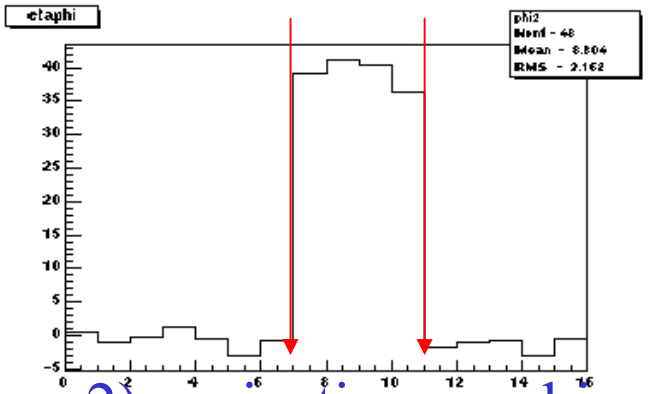
1) projection on phi

Result:Wrong

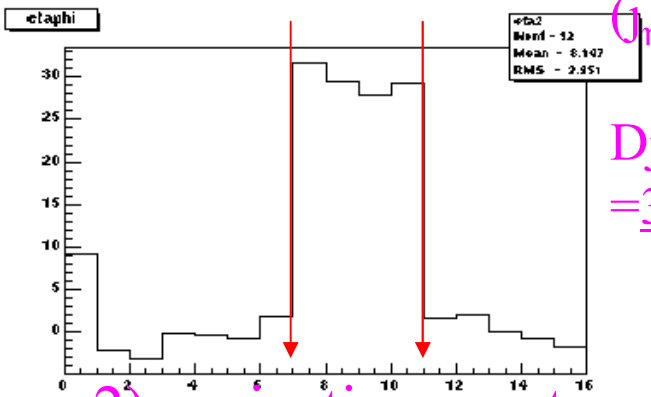
$(\eta,\phi)=(7,1)$

$(j_\eta,j_\phi)=(2,4)$

$Djkmax^2$ =3179.54



2) projection on phi



2) projection on eta

Binomial Distribution as a Baseline Fluctuation

- **We need to define a degree of the anomaly quantitatively with a familiar statistical language.**
- **Suppose that we have *m* charged tracks and *n* γ-clusters in our total detector acceptance in a given event. If we distribute them independently into the acceptance, the asymmetry found in a given subdivided phase space must follow asymmetry based on binomial distributions.**
- **We apply 2-D MRA to those simple binomial samples.**
- **We can get correspondence between Djkmax^2 and probability to exclude the binomial sample.**

$$p^{(j_\eta,j_\phi)} \equiv 2^{-(j_\eta+j_\phi)}$$

$$B_m{}^{(j_\eta,j_\phi)}(x) \equiv {}_mC_x\{p^{(j_\eta,j_\phi)}\}^x\{1-p^{(j_\eta,j_\phi)}\}^{m-x}$$

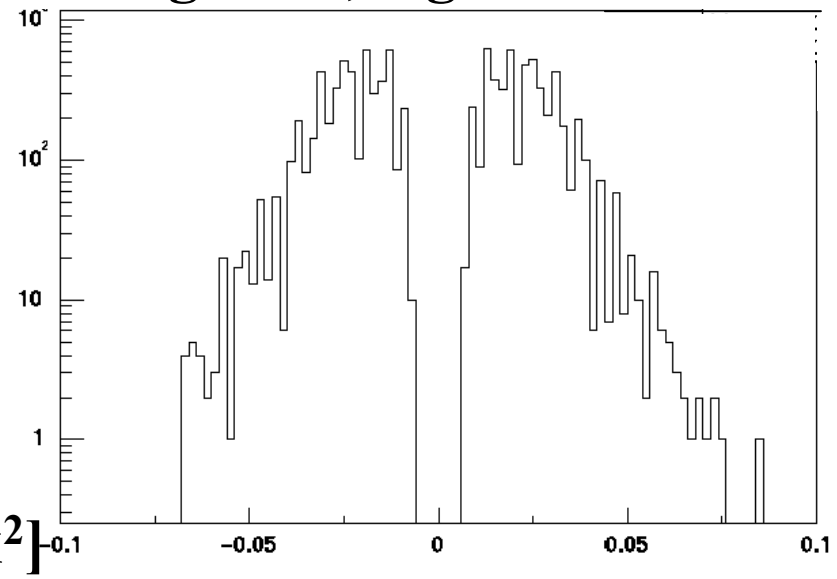
$$B_n{}^{(j_\eta,j_\phi)}(y) \equiv {}_nC_y\{p^{(j_\eta,j_\phi)}\}^y\{1-p^{(j_\eta,j_\phi)}\}^{n-y}$$

$$d \equiv x - y = \delta A_{I3} \cdot \sqrt{m+n}$$

$$P_{(m,n)}{}^{(j_\eta,j_\phi)}(d) = \sum_{i=\max(d,0)}^{\min(n,m+d)} B_n{}^{(j_\eta,j_\phi)}(i) B_m{}^{(j_\eta,j_\phi)}(i-d)$$

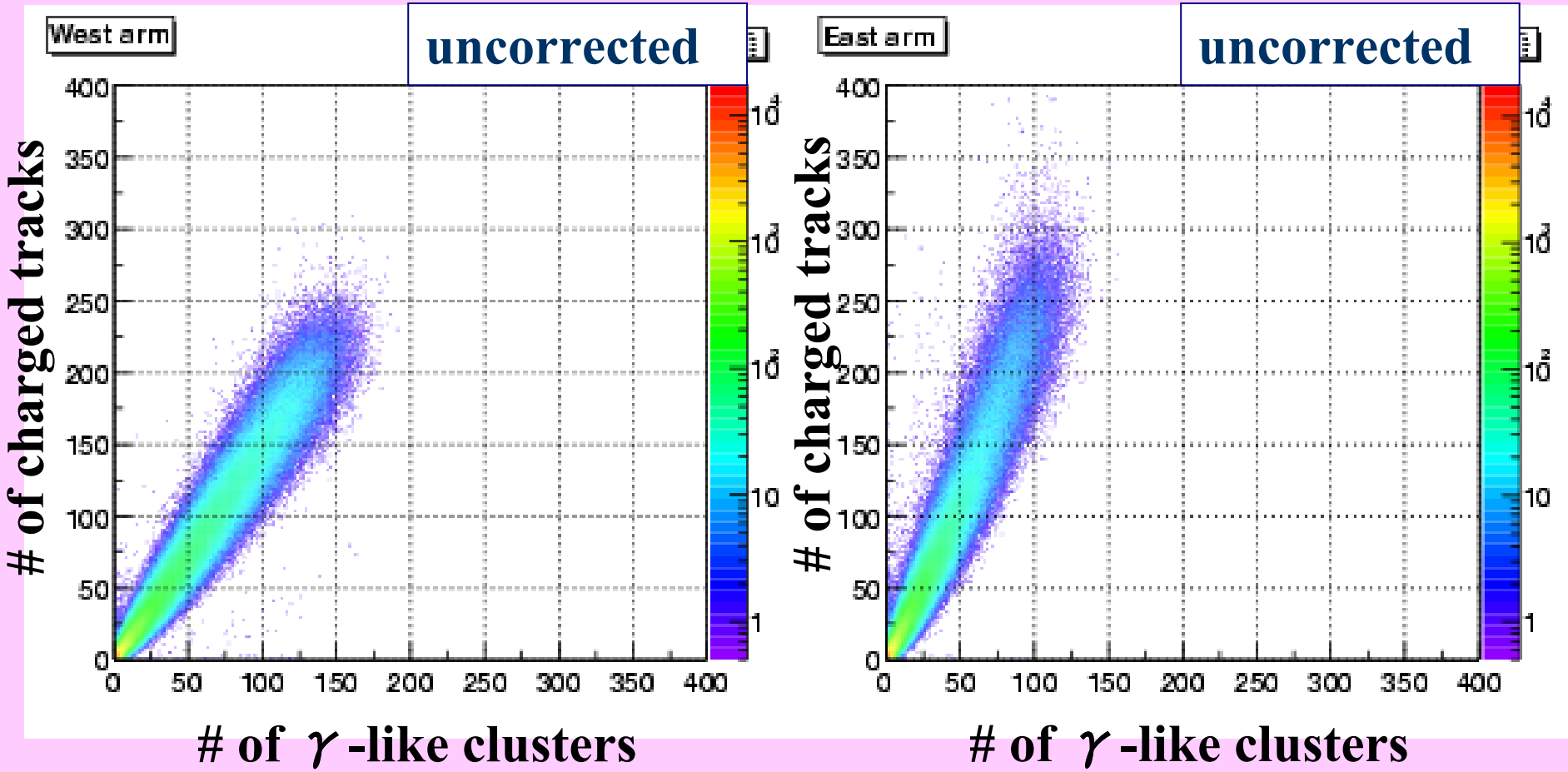
$$m \geq 0, n \geq 0, -m \leq d \leq n$$

#charge:100, #gamma-like:100



[Djkmax^2]

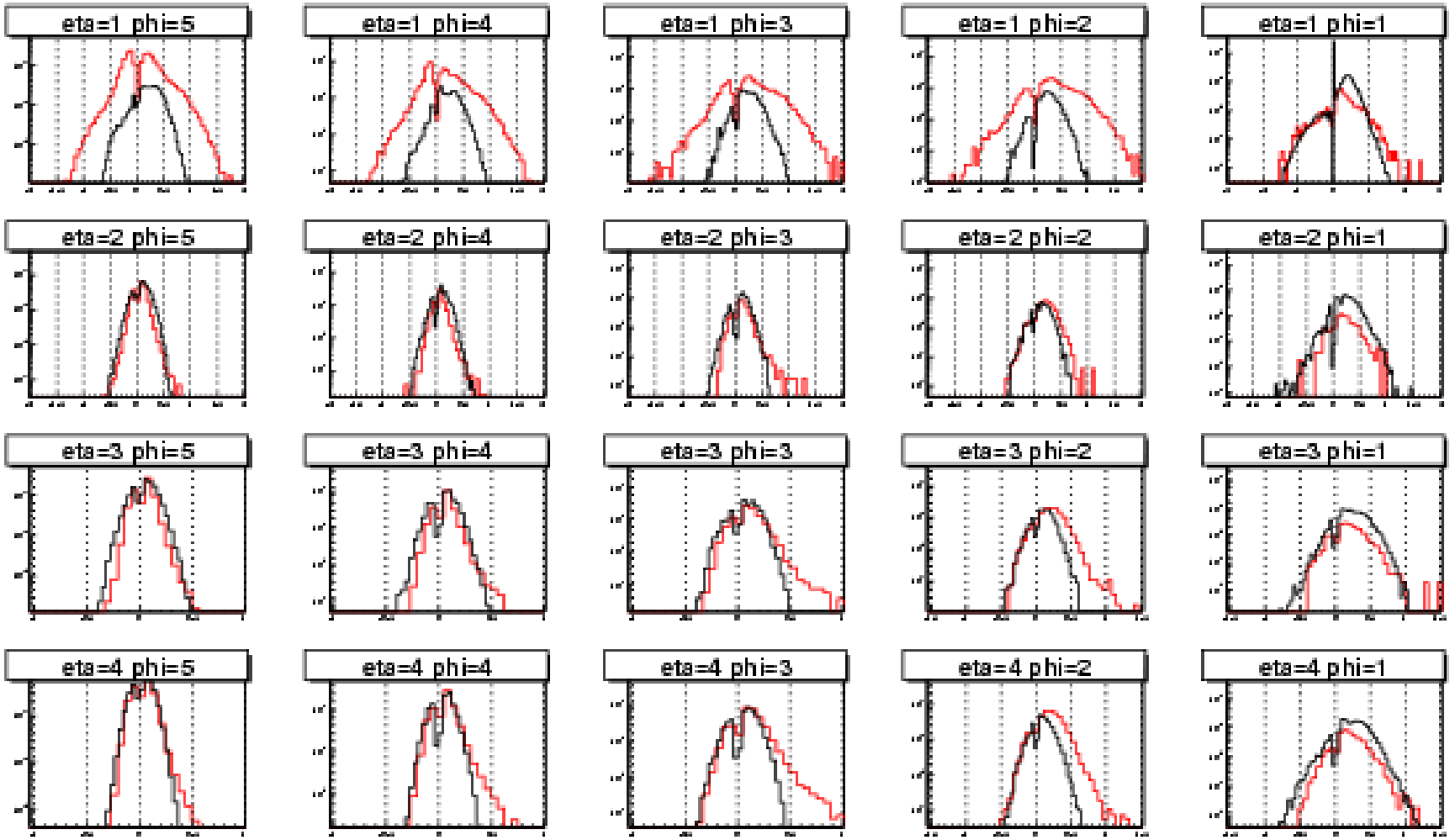
Correlation between Charged Tracks and Gamma-like Clusters



Maximum Deviation Size (Djkmax^2)

Data minimum bias in West Arm

uncorrected



$\Delta\eta$: 0.350 0.175 0.088 0.044

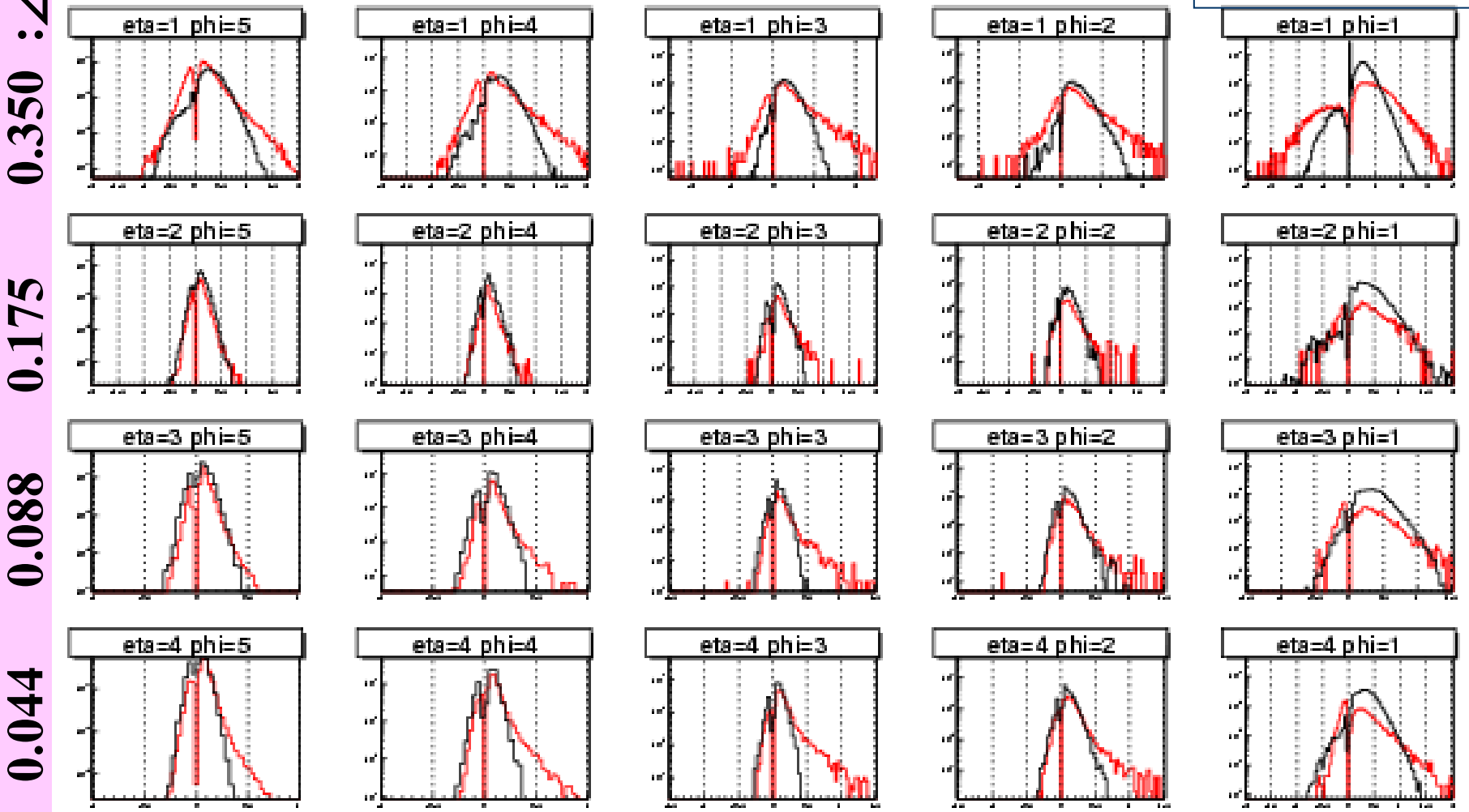
ΔPhi : 2.813° 5.625° 11.25° 22.50° 45.00°

(# of charge > 1, # of gamma > 1)

- Red : Data
- Black : Binomial

Data minimum bias in East Arm

uncorrected

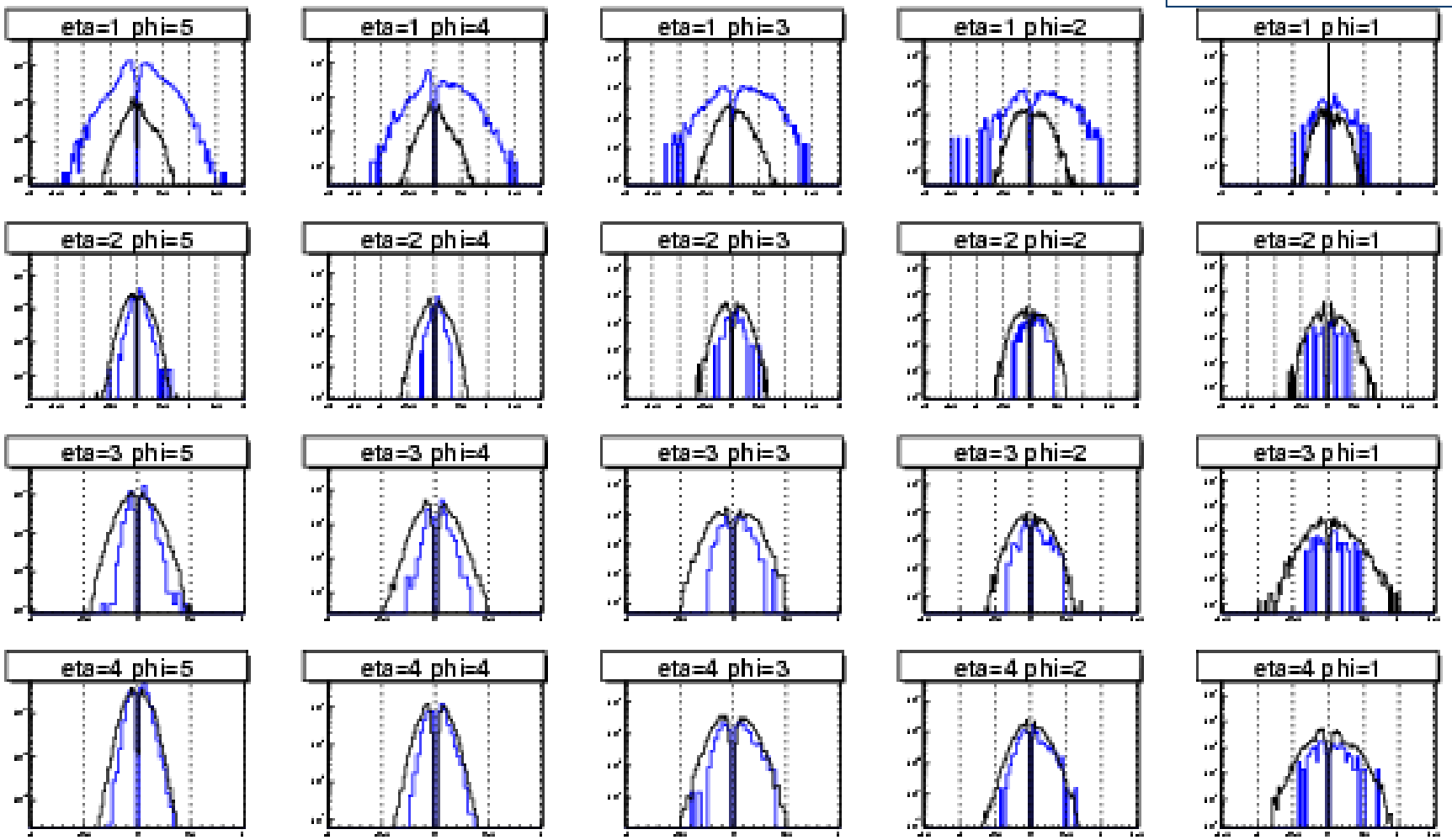


Δ Phi : 2.813° 5.625° 11.25° 22.50° 45.00°

Maximum Deviation Size (Djkmax^2)

HIJING minimum bias in West Arm

uncorrected



$\Delta\eta$: 0.350 0.175 0.088 0.044

ΔPhi : 2.813° 5.625° 11.25° 22.50° 45.00°

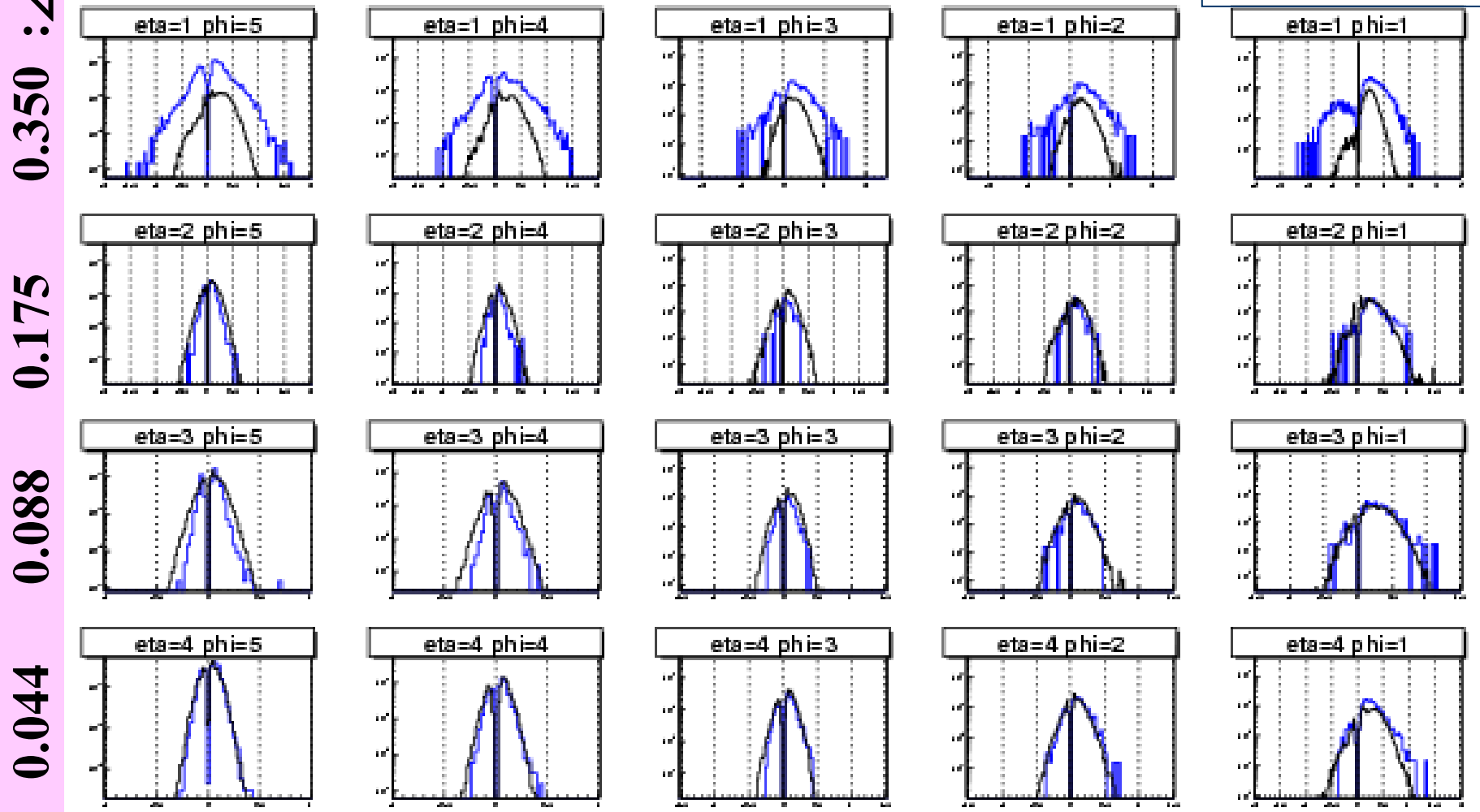
(# of charge > 1, # of gamma > 1)

- Blue : HIJING
- Black : Binomial

PHENIX

HIJING minimum bias in East Arm

uncorrected



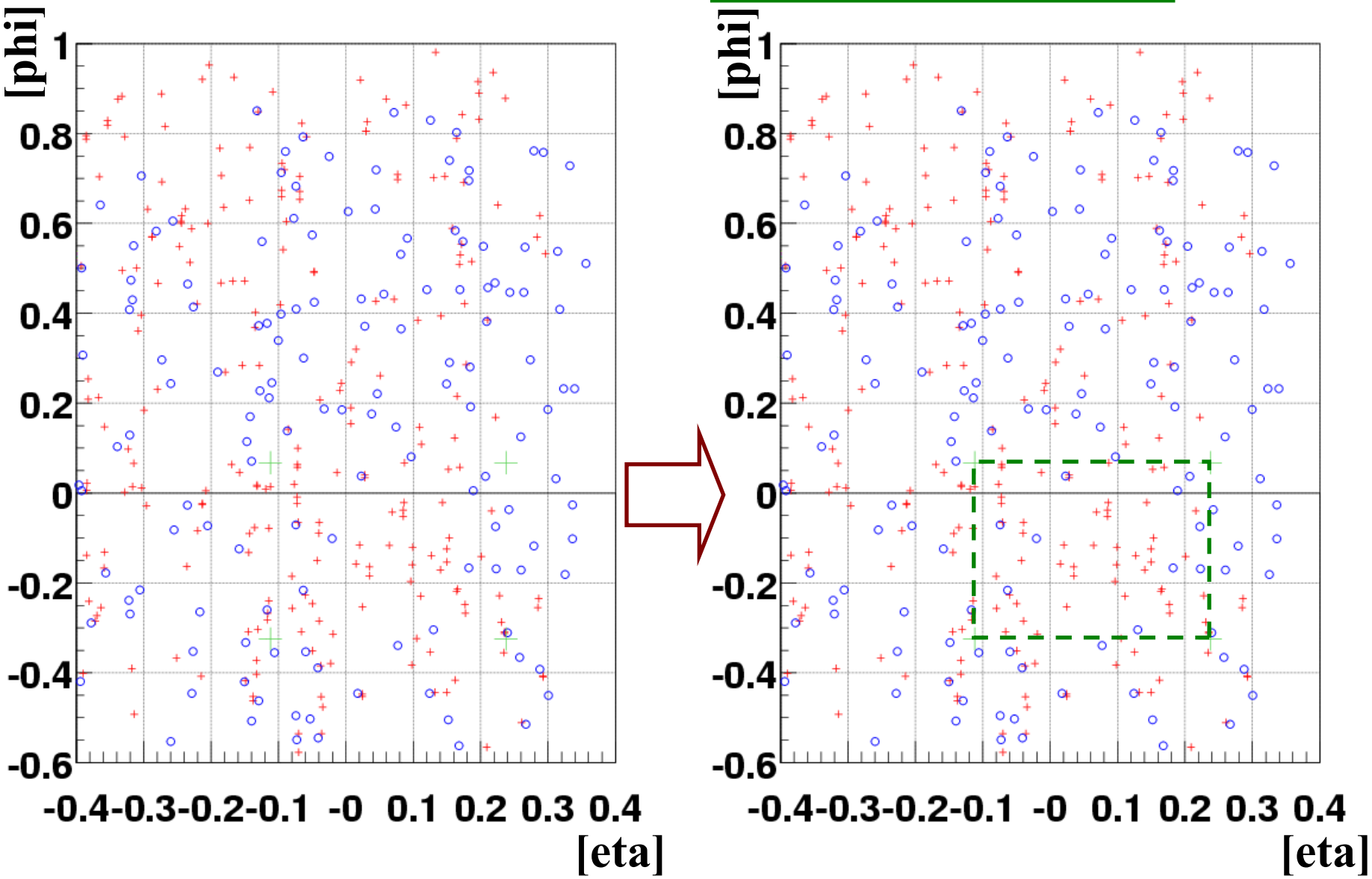
Δ Phi : 2.813° 5.625° 11.25° 22.50° 45.00°

Centauro Type (West)

Djkmax^2 : 1.698

# of gamma-like : 10

# of charged : 55

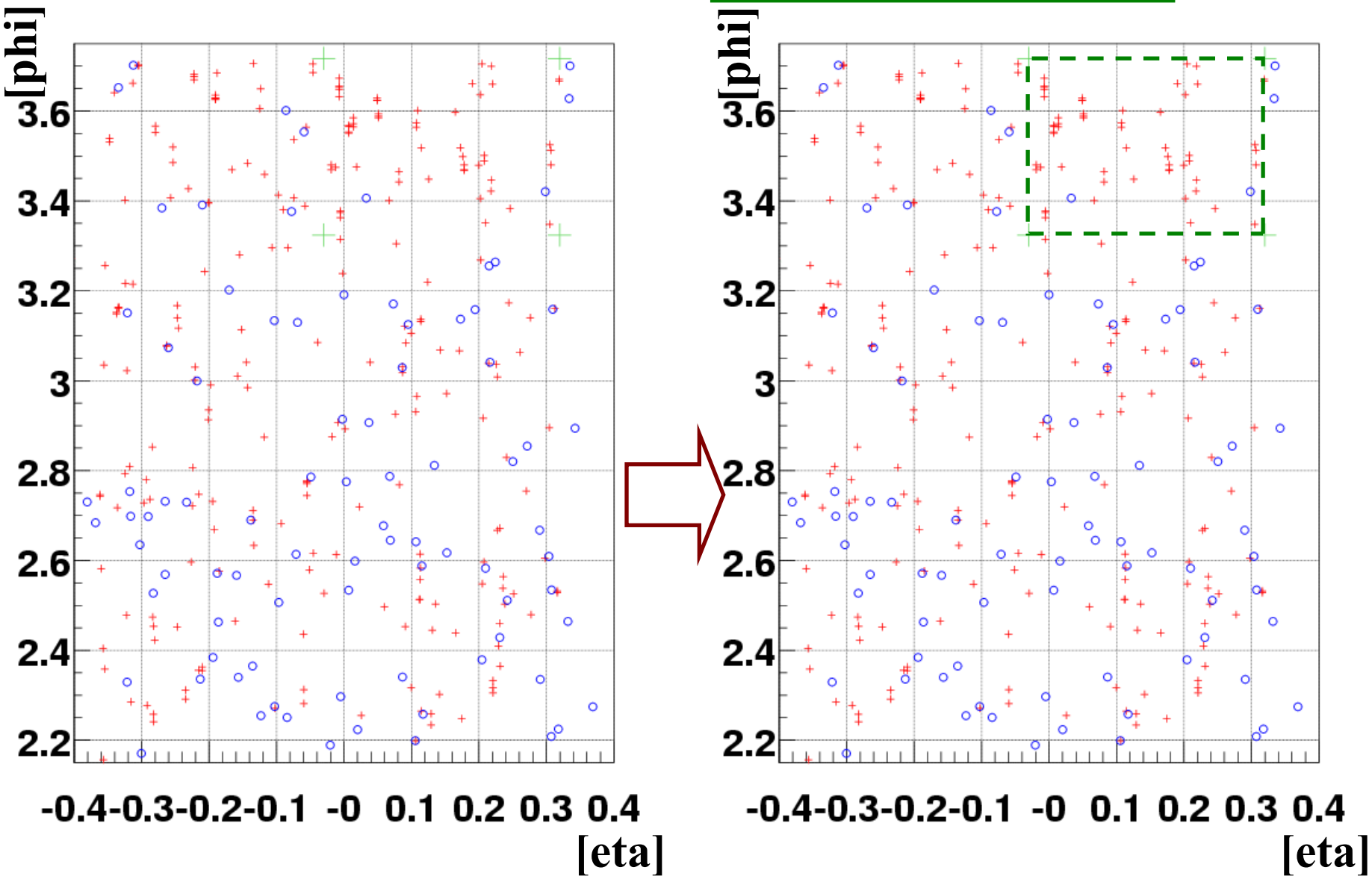


Centauro Type (East)

Djkmax^2 : 2.251

# of gamma-like : 2

# of charged : 49

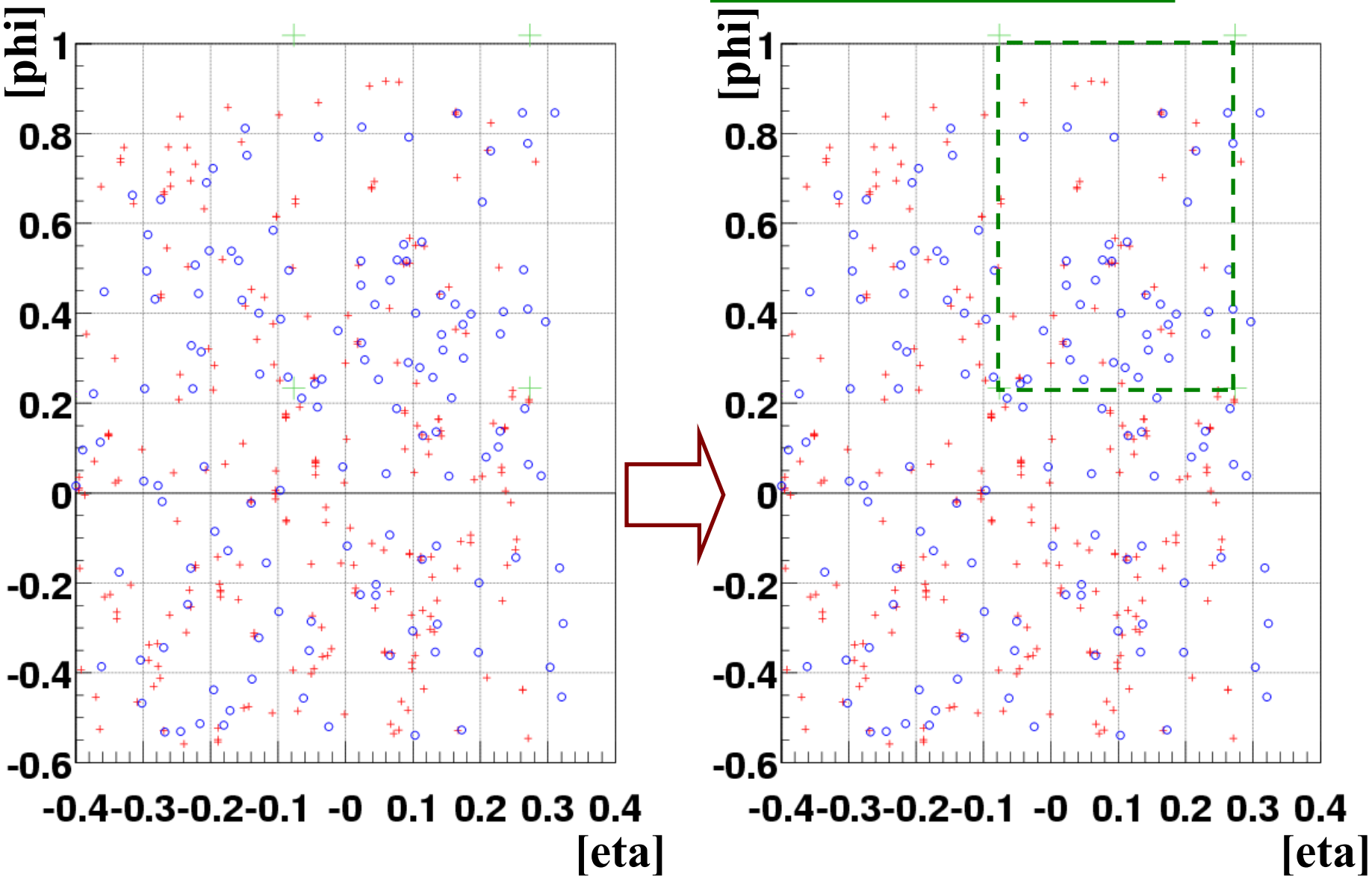


Anti Centauro Type

Djkmax^2 : -1.638

# of gamma-like : 36

# of charged : 28



Summary and Future Plan

- **We have demonstrated two dimensional multi-resolution analysis on the asymmetry between the number of the charged tracks and γ-like clusters in the η-ϕ phase space. (See below)**
- **More understanding of detector biases is necessary.**
- **Set a reasonable significance level to define the degree of anomaly based on the physical models with normal fluctuations.**
- **Count the anomalous events above the significance level.**
- **Discuss the event characters of those events, if they are found.**